Buletin Peternakan 43 (1): 8-16, February 2019

ISSTAP
Indonesian Society for Sustainable Tropical Animal Production

Bulletin of Animal Science

ISSN-0126-4400/E-ISSN-2407-876X Accredited: 36a/E/KPT/2016
http://buletinpeternakan.fapet.ugm.ac.id/

Doi: 10.21059/buletinpeternak.v43i1.37648

Thermoregulation, Haematological Profile and Productivity of Holstein Friesian Under Heat Stress at Different Land Elevations

Elmy Mariana[1]*, Cece Sumantri[2], Dewi Apri Astuti[3], Anneke Anggraeni[4], and Asep Gunawan[4]

[1]Department of Animal Production and Technology, Faculty of Agriculture, Syiah Kuala University, Banda Aceh, 23111, Indonesia
[2]Department of Animal Production and Technology, Faculty of Animal Science, Bogor Agricultural University, Bogor, 16680, Indonesia
[3]Department of Nutrition and Feed Technology, Faculty of Animal Science, Bogor Agricultural University, Bogor, 16680, Indonesia
[4]Research Institute for Animal Production, Ciawi Bogor, 16002, Indonesia

Article history
Submitted: 30 July 2018
Accepted: 16 January 2019

* Corresponding author:
Telp. +62 85260524076
E-mail: elmy_mariana@unsyiah.ac.id

ABSTRACT

The purpose of this research was to determine the effect of heat stress on thermoregulation, haematology, and productivity of Holstein Friesian (HF) dairy cows raised in different elevations. A total of 63 HF in a normal lactation period were used in this study. The research was conducted for 3 months during dry season in three different areas, which were at Pondok Ranggon (97 m.a.s.l) which categorized as a lowland, Ciawi (576 m.a.s.l) which categorized as a lower-upland, and Lembang (1241 m.a.s.l) which categorized as an upland. Observation on microclimate aspects which includes environmental temperature (Ta), relative humidity (RH) and Temperature-Humidity Index (THI) was done by recording each variable for every 2 hours starting from 08.00 to 16.00 WIB. The thermoregulation analysis was done based on the given physiological responses which consisted of the skin temperature (Ts), rectal temperature (Tr), body temperature (Tb), heart rate (Hr), respiratory rate (Rr), Heat Tolerance Coefficient (HTC), plasma cortisol level and haematological profile observation. The Ta, Rr, and THI measurements showed that in the lowland and lower-upland, the HF experienced moderate heat stress, while the HF raised in the upland area experienced less heat stress. The results showed that the dairy cows which raised in lowland had the highest HTC, Tr, Ts and Tb ($P<0.05$) and lowest Hr ($P<0.05$). All of the physiological and haematological parameters in the three study area showed a normal value. Furthermore, the erythrocyte, Hb and PVC concentration in a lowland raised HF were higher ($P<0.05$), while the plasma cortisol levels were not significantly different. The milk production of the observed dairy cows in different elevations was significantly different ($P<0.05$), with the highest milk yields, were found in the upland raised HF (13.1±3.52 kg), followed by the lower-upland (11.3±4.73 kg) and lowland (7.0±3.36 kg). In general, all of the HF raised in different land elevations was exposed to heat stress during dry seasons, even though the cows showed the ability to physiologically adapt and cope with the conditions.

Keyword: Elevation, Dairy cattle, Haematology, Heat stress, Productivity, Thermoregulation

Introduction

The dairy industry in Indonesia showed promising prospects to be continuously developed, regarding that the current national milk production still fulfills 23% of the domestic needs (Ditjennak, 2017). Moreover, most of the national milk production is provided by dairy cow farming, thus to further improve the milk production, an increase in dairy cow population and farming scale should be done. The current dairy cow farm practice was mostly concentrated in the upland areas, such as Pangalengan, Lembang, Baturaden, Batu, Pujon, and Nongkojajar, while the practice in lowland and/or lower-upland is still rare. The lowland is an area characterized by high temperature and humidity, which are known to inhibit dairy farming development. The opportunity to develop dairy farms in lowland can only be realized if those factors are dealt with. The air temperature and humidity are the most important environmental factors which affect dairy cow adaptation, distribution, and vegetation. Research showed that relatively high air temperature combined with high humidity could negatively affect dairy cow production and reproduction (Purwanto *et al*., 1993; Atrian and Shahryar, 2012). The dairy cow could yield good productivity when raised in an environment with suitable temperature and humidity known as a comfort zone. On the contrary, the dairy cow would have experienced stress, declining productivity (Purwanto *et al*., 1993; Nardone *et al*., 2010) and milk quality (Hill and Wall, 2015) when raised outside its comfort zone. Research has shown that heat stress on a dairy cow would decline its milk production up to 0.6-1.4 kg for every 1ºC increased temperature (Atrian and Shahryar, 2012). St-Pierre *et al.* (2003) stated that the US had experienced loss at about USD 900 million due to the declining milk production caused by heat stress. During heat stress, the dairy cow adapts by increasing its heat dissipation through skin evaporation and respiration, and these affect on declining feed intake, blood redistribution, declining immunity, and changes in endocrine function (Marai *et al*., 2007). The thyroid and cortisol hormone is also known to play an important role in the adaptation process (Todini *et al*., 2007), especially on the general metabolic process. Moreover, an increase in the dairy cow body temperature is known to be tightly correlated with the decrease in thyroid gland activity which caused lower thyroid concentration and higher cortisol concentration (Megahed *et al*., 2008; Soltan, 2010). The condition thus caused cortisol concentration to be one of the physiological stress parameters. A change in animal physiology is the basis of animal thermoregulation to maintain temperature stability and to prevent hyperthermia. Research of heat stress on dairy cows correlated with different land elevations is still rarely done in Indonesia. The purpose of this research is then to observe the effect of heat stress on different land elevations to the HF dairy cow adaptation and productivity. The result of this research is hoped to be able to provide guidance to conduct a sustainable dairy farm development plans regarding the farm elevation.

Materials and Methods

Place and time of the research

The research was conducted on three different locations, which were Technical Implementation Unit for Production and Animal Health, Department of Forestry, Marine, and Food Security of Jakarta Special Capital Region (Pondok Ranggon), Dairy Research Station (Ciawi), and Technical Implementation Unit for Dairy and Forages Research Cikole (Lembang). The general conditions of the research area were presented in Table 1.

The research was conducted in May until October 2015, in which dry season was occurred with lowest rainfall intensity and highest temperature according to the Indonesian Department of Meteorology, Climatology, and Geophysics (BMKG).

Materials

The Holstein Friesian (HF) breed with around 2–4 lactation months and 2–4 lactation periods was used in this research. A total of 63 HF were divided into three different areas (29 cows in Pondok Ranggon, 15 cows in Ciawi, and 19 cows in Cikole), and purposive sampling method was used to choose the research sample.

The cows were placed in a barn with a decent feed and water container, while also raised following the standard of Good Dairy Farming Practices (GDFP) (FAO, 2011). The given feed includes forages, feed concentrates and additives which fulfills the nutritional requirement by the NRC (2001). The feed composition in this research is presented in Table 2.

Observed parameters

The observed parameters in this study include environmental conditions, physiological responses, the heat tolerance coefficient (HTC), plasma cortisol levels, haematology profile, and milk production. The observed environmental conditions were climatological data from BMKG, elevation, topography, microclimate conditions (air temperature, humidity and wind speed). The microclimate conditions were observed for every 2 hours starting from 08.00 AM to 16.00 PM. The air temperature and humidity were measured by using dry-wet bulb thermometer (dry wet, Shanghai). The Temperature-Humidity Index was calculated following Hahn (1999) formula as follows:

$$THI = DBT + 0.36\ WBT + 41.2,$$

The DBT is the temperature of the dry bulb (ºC), while WBT is the temperature of the wet bulb (ºC).

The other microclimate data such as monthly and annual air temperature, rainfall intensity, solar irradiance, air humidity, and wind speed were collected as secondary data provided by BMKG. Milk yields productivity was measured in the morning and afternoon milking. The milk production data is the mean value of 305-days milk yield and corrected wit 4% fat corrected milk (FCM) to remove the fat factors by the following formula:

$$\text{Milk production 4\% FCM} = (0.4 \times PS) + (15 \times PS \times L),$$

PS is the average daily milk production, and L is the milk fat percentage.

The observed physiological responses include the skin temperature (Ts), rectal temperature (Tr), body temperature (Tb), heart rate (Hr), and respiratory rate (Rr). The Tr was measured by using a rectal thermometer (SAFETY, Japan) into the rectum about 10 cm deep for 3 minutes. The infrared thermometer (Traceable MiniIR™ Thermometer, Friendswood, Texas, USA) was used to measure Ts in four

Table 1. General conditions of the research area

Parameters	Lowland	Lower-upland	Upland
Elevation (m.a.s.l)	97	574	1241
Position	06° 15' S 106° 54' E	6°40' S 106°51' E	06 °.50' S 107 °.37' E
Topography	Slopped terrain	Hilly terrain	Hilly terrain
Ta (°C)	22 – 35.9	19.7-22.5	13.8 – 21.8
Average Ta (°C)	27.5	21.2	20.1
RH (%)	76.9	84	82.3
Wind speed (m/s)	3.68	1.56	3.19
Rainfall intensity (mm/year)	2583	3810	2293

Source: The Indonesian Department of Meteorology, Climatology, and Geophysics (BMKG) data tabulation from 2004 to 2014.

Table 2. Feed intake and composition

	Feed intake	DM	EE	CP	CF	Ca	P
		----------------------Kg/cow/day---------------					
Lowland							
Forage	30	13.30	0.15	0.46	4.39	16	12
Feed concentrate	2	1.77	0.09	0.20	0.16	16	10
Feed additive	20	2.53	0.24	0.48	0.40	11	6
Total consumption	52	17.6	0.48	1.14	4.95	43	28
Lower-upland							
Forage	22	5.64	0.31	0.41	1.58	20	10
Feed concentrate	6.5	5.70	0.08	0.92	0.56	66	16
Feed additive	6.5	1.17	0.46	0.20	0.22	4	03
Total consumption	35	12.51	0.13	1.53	2.36	90	29
Upland							
Forage	45	7.63	0.13	0.82	2.12	26.7	11.8
Feed concentrate	10.5	8.83	0.56	1.14	1.37	83.1	39.1
Feed additive	5	1.26	0.11	0.31	0.2	10	4
Total consumption	60.5	17.72	0.8	2.27	3.69	119.8	54.9

different areas, which at topline (A), chest (B), front leg (C), and back leg (D). The average skin temperature was measured by following McLean *et al*. (1983) formula as follows:

Ts = 0.25 (A + B) + 0.32 C + 0.18 D

The body temperature (Tb) was measured by the following formula:

Tb = 0.86 Tr + 0.14 Ts.

The heart rate was measured by using a stethoscope (STETHOSCOPE, Japan) near the left axilla (left chest) for 1 minute. The respiration rate was measured by using a stethoscope in the chest area to count the inspiration and expiration rate for 1 minute. The Ts, Tr, Tb, Rr, and Hr measurement was done every day at 08.00 AM, 12.00 PM, and 16.00 PM. The heat tolerance coefficient (HTC) was measured based on the respiration rate per minute and rectal temperature. The HTC was measured by the following formula:

$$HTC = \frac{Tb}{38.3} + \frac{Rr}{23}$$

Description

Tb = Average daily body temperature (°C)

Rr = Average respiration rate for 1 minute

38.3 = Standard body temperature of a dairy cow

23 = Standard respiration rate for 1 minute.

The plasma cortisol level was measured by using an Enzyme-Linked Immunosorbent Assay (ELISA). The blood sample was taken through veins in the tail, and rested for 16 hours at ±3°C before harvested for the blood plasma. The plasma cortisol level was analyzed by using the ELISA kit by Diagnostic Automation. Inc. USA.

The haematology variables observed in this research include erythrocyte concentrations, pack volume cell (PVC), blood haemoglobin (Hb) level, total leukocyte and leukocyte differentiation (neutrophils, eosinophils, basophils, monocytes, and lymphocytes concentration, and also neutrophils and lymphocytes ratio or N/L ratio). All of the haematology profile variables were measured according to Campbell (1995).

Data analysis

The macroclimates, microclimates, THI, physiological responses, haematology profile, plasma cortisol levels, and milk production data were analyzed with the General Linear Model approach. The analysis was done based on the different area elevations, and if the response showed different effects (α=0.05), it would be followed by Duncan's Multiple Range test.

Result and Discussion

Environmental conditions

The research was conducted in three different dairy farm areas (Table 1). The lowland dairy farm is represented by Technical Implementation Unit for Dairy Cows in Pondok Ranggok, East Jakarta; the lower-upland dairy farm is represented by Dairy Research Station in Ciawi; and the upland dairy farm is represented by Technical Implementation Unit for Dairy and Forages Research in Cikole, Bandung. The environmental microclimates data were observed from 08.00 AM to 16.00 PM which can be seen in Table 3.

The average air temperature in all three areas during the research time is higher compared to the average temperature in the last 10 years. It regards that Indonesia had experienced El-Nino in 2015, which caused longer dry season along with

Table 3. Research area microclimate conditions

Parameters	Time	Elevation			
		Lowland	Lower-upland	Upland	Mean value
Ta (oC)	08.00	27.1±2.19	23.6±1.50	24.7±0.80	25.1±0.21[C]
	10.00	32.7±1.25	27.7±1.01	28.0±0.96	29.5±0.21[B]
	12.00	35.4±1.62	30.4±0.73	29.1±1.34	31.6±0.21[A]
	14.00	36.7±1.68	31.7±0.88	29.3±1.17	32.6±0.21[A]
	16.00	33.4±3.21	31.5±1.89	26.3±1.06	30.4±0.21[B]
	Mean	33.1±3.91[a]	28.9±9.01[b]	25.7±4.41[c]	
RH (%)	08.00	81.6±7.68	79.1±6.81	58.6±5.58	73.1±1.15[A]
	10.00	55.0±4.40	65.3±4.74	51.6±6.08	57.3±1.15[B]
	12.00	45.5±4.12	56.2±5.01	46.9±6.22	49.5±1.15[C]
	14.00	43.4±3.60	53.3±5.51	44.4±6.17	47.0±1.16[C]
	16.00	58.0±12.56	54.0±10.16	57.8±10.91	56.2±1.16[B]
	Mean	61.8±15.40[a]	57.2±14.02[ab]	56.7±14.82[b]	
THI	08.00	77.2±2.60	72.3±1.75	72.8±1.35	74.1±0.24[C]
	10.00	83.0±1.48	77.0±1.27	76.5±1.14	78.8±0.24[B]
	12.00	85.8±1.84	80.1±0.94	77.6±1.52	81.1±0.24[A]
	14.00	87.5±1.94	81.5±0.94	77.6±1.40	82.2±0.24[A]
	16.00	84.0±3.44	81.2±1.98	74.7±1.12	78.0±0.24[B]
	Mean	83.5 ± 4.19[a]	78.3±9.33[b]	73.8±5.10[c]	

Different lowercase superscripts on the same row showed a significant difference (P<0.05).
Different uppercase superscripts in the same column showed a significant difference (P<0.05).

an increase in the air temperature (BMKG, 2015). The temperature during research is ranging around 23.6-36.7^{o}C, with humidity at 43.4-81.6%, and THI at 72.3–87.5. The obtained THI value is higher to the comfort THI standard for a dairy cow, which is less than 72. The THI measurement then showed that the lowland area induced moderate stress to the dairy cow, while on the lower-upland and upland area, the dairy cow experienced mild stress. Atrian and Shahryar (2012) stated that the stress level caused by environment condition based on the THI value is categorized in 4 groups, which are mild stress (THI 72-78), moderate stress (THI 79-88), severe stress (THI 89-98) and extreme stress (THI>98).

The THI measurement on all three areas showed that the index reached more than 72 on the morning observation, which showed that the cows had already experienced mild stress. The highest THI value was occurred at 14.00 PM on the lowland and lower-upland area, while the highest THI value occurred at 12.00 PM in the upland area. The similar condition is shown in research by Yani and Purwanto (2006) which reported that the temperature began to increase during daytime and reached its highest temperature at 12.00-14.00 PM then began to decrease during the afternoon, while the air humidity showed an opposite pattern.

Physiological responses

The heat stress experienced by HF dairy cows can be determined through THI measurement and physiological responses observation. The physiological responses observation on all three different areas is presented in Table 4. The analysis of variance (Table 4) showed that the land elevation and observation time affect the physiological responses of the dairy cow which can be seen from its Rr, Hr, Tr, Ts, Tb, and HTC (P<0.05).

The Tr, Ts, and Tb on lowland were higher compared to the lower-upland and upland. Moreover, the HF dairy cow which raised in lower-upland had the same Tr and Tb to the upland but had higher Ts. It is allegedly caused by the lower wind speed in the lower-upland area to the upland area, which resulted in slower heat dissipation to the environment through skin radiation in the lower-upland area. The highest Tr was shown at 16.00 PM in all of the research areas. The condition is known to be caused by the combined effect of the air temperature which reached its peak at 14.00 PM and the cow metabolism due to feed digestion. In all of the research areas, the cows were fed at 15.00 PM or after milked. Purwanto *et al.* (1990) stated that the highest body heat production is reached 3 hours after being fed. The change in rectal temperature indicates the dairy cow's response to the surrounding environment (Nardone *et al.,* 2010). Furthermore, the rectal temperature is also affected by the cow's behavior, feed intake and the surrounding temperature (Das *et al.,* 2016).

The effect of land elevation to the Rr can be seen from the respiration rate (Rr) which showed significant differences (P<0.05) between HF dairy cows which raised in the lowland, lower-upland, and upland area. The average Rr on the lower-upland (49.9±0.57) was higher compared to the lowland and upland. This showed that the dairy cows which raised in the lower-upland area could not remove its heat load enough so that the cows would increase its respiration rate to remove the heat load through the evaporation process. The Rr is a very sensitive indicator to determine animal heat stress (Sejian *et al.*, 2013), in which Rr at 80-90 times/minute indicates that the dairy cows experienced stress (Mirzadeh *et al.*, 2010). It is also supported by Collier *et al.* (2007) which stated that the normal respiration rate of the cow is around 54 times/minute.

The heart rate (Hr) analysis showed significant differences between HF dairy cows raised in all research areas. The average Hr in this research was around 68.5-80.0 BPM, with the highest Hr was showed in the HF dairy cows raised in the upland area (78.8±0.65). The

Table 4. The effect of land elevation on the physiological response of HF dairy cow

Parameters	Time	Elevation			
		Lowland	Lower-upland	Upland	Mean value
Tr (^{o}C)	08.00	37.5±1.26	37.4±0.65	37.4±3.09	37.5±0.07^B
	12.00	38.3±0.43	38.0±0.64	38.0±0.53	38.1±0.07^A
	16.00	38.6±0.56	38.3±0.46	38.1±0.99	38.3±0.07^A
	Mean	38.1±0.08^a	37.9±0.07^b	37.8±0.07^b	
Ts (^{o}C)	08.00	31.1±1.33	29.8±1.29	31.0±1.32	30.5±0.06^C
	12.00	34.7±1.43	34.0±0.77	33.3±1.04	33.9±0.06^A
	16.00	33.8±1.36	34.1±0.70	31.9±0.91	33.2±0.06^B
	Mean	33.2±0.07^a	32.6±0.06^b	32.1±0.06^c	
Tb (^{o}C)	08.00	36.6±1.14	36.4±0.64	36.3±3.85	36.4±0.10^B
	12.00	37.8±0.45	37.2±2.75	37.4±0.48	37.4±0.10^A
	16.00	37.9±0.56	37.7±0.43	37.2±0.89	37.6±0.10^A
	Mean	37.4±0.11^a	37.1±0.09^b	37.0±0.09^b	
Rr/min	08.00±	33.1±10.44	38.5±9.30	34.1±8.36	35.5±0.62^B
	12.00	51.0±14.76	53.4±14.15	38.5±10.03	47.1±0.62^A
	16.00	48.0±11.26	57.7±14.49	39.9±7.85	48.6±0.62^A
	Mean	44.0±0.71^b	49.9±0.57^a	37.5±0.57^c	
Hr (BPM)	08.00	61.8±9.72	70.1±13.91	73.0±8.99	69.2±0.71^C
	12.00	67.8±12.27	72.0±17.43	77.3±10.26	73.0±0.71^B
	16.00	67.7±11.03	75.7±16.07	86.0±12.85	77.7±0.71^A
	Mean	65.8±0.82^c	72.6±0.65^b	78.8±0.65^a	
HTC	08.00	2.4±0.46	2.6±0.56	2.4±0.35	2.4±0.34^A
	12.00	3.2±0.65	3.2±0.79	2.7±0.44	2.9±0.48^B
	16.00	3.1±0.50	3.5±0.63	2.7±0.34	3.2±0.70^C
	Mean	2.9±0.65^b	3.1±0.77^a	2.6±0.40^c	

Different lowercase superscripts on the same row showed a significant difference (P<0.05).
Different uppercase superscripts in the same column showed a significant difference (P<0.05).

significant Hr differences were caused by several factors, such as microclimates, body size, and cows' productivity. The heart rate activity is known to be tightly correlated with milk production and feed intake. The HF dairy cows which raised in the upland area had the highest productivity and feed intake compared to the lowland and lower-upland area. Purwanto *et al*. (1993) stated that the high feed intake of the cow resulted in high body heat production due to metabolism.

Moreover, high energy consumption would produce high body heat and further prompted physiological response to the heat load such as increasing heart rate (Brosh *et al.,* 2005). Reece *et al*. (2015) also stated that the increased heart rate is an animal adaptation to maintain its body heat. Furthermore, an increased heart rate would increase heat dissipation through peripheral circulation (Das *et al*., 2012).

The highest Tr, Ts, and Tb from all research areas was 38.6±0.56; 34.1±0.70 and 37.9±0.56 respectively. The obtained result is categorized as normal for lactating dairy cows according to Schütz *et al.* (2011). The result also showed that the dairy cows were still able to maintain its homeostatic condition to its environmental condition. The capability to maintain its homeostatic condition is also shown from the increasing rectal temperature, which was not significantly different, during the peak stress period (at 12.00 to 14.00 PM) and low HTC. The highest HTC was found in the lower-upland area, and the lowest was found in the upland area. This showed that the HF dairy cows which raised in the upland area had better tolerance to stress compared to the HF dairy cows raised in other research areas. It is also supported by the better respiration rate, rectal, body, and skin temperature of the HF dairy cows which raised in the upland area compared to others.

Plasma cortisol level and haematological profile

Aside from the physiological response, the haematological profile and plasma cortisol level of the dairy cow would also represent its adaptation capability under heat stress. The plasma cortisol level and haematological profile in this research are presented in Table 5.

Plasma cortisol levels in all of the HF dairy cows in different research areas showed no significant difference, whether raised on the lowland, lower-upland and upland area, even though the cows in each area experienced different heat stress level. The result of this research is in contrary to the finding of other previous researches which reported that the increase of heat stress would result in an increased plasma cortisol levels in bulls (Megahed *et al*., 2008; Kumar *et al.,* 2011), Black Bengal goats (Sivakumar and Singh*,* 2010), lactating dairy cows (Soltan, 2010), Sahiwal cattle (Bhan *et al*., 2012), Malpura goats (Sejian *et al.*, 2013) and Ardi goats (Al-Samawi *et al*., 2014). The cortisol production under heat stress is caused by HPA axis activity which stimulates the hypothalamus to release corticotrophin-releasing factor that prompted anterior pituitary to release adrenocorticotropic hormone (ACTH). The process then caused adrenal cortex to produce glucocorticoid which includes cortisols (Silanikove, 2000; Marai *et al.*, 2007). The release of glucocorticoid under heat stress condition is correlated to the heat shock response intracellular modification. An increase of glucocorticoid on the cytoplasm receptors would stimulate the release of HSP 70 and HSP 90 in cells, in which would reduce the risk of protein refolding caused by the heat stress (Todini *et al*., 2007). This process thus showed that the plasma cortisol level is one of the important factors to analyze heat stress.

Table 5. Comparison of plasma cortisol level and haematological profile of the HF dairy cows

Variables	Lowland	Lower-upland	Upland	Mean Value
Cortisol (ug/dL)	0.8±1.13	4.1±5.51	10.0±14.48	5.7±10.34
Erythrocytes (x10[6]/uL)	6.4±0.37[c]	9.1±1.88[a]	7.7±1.01[b]	7.9±1.63
PVC (%)	24.1±2.62[ab]	24.9±3.7[a]	21.6±4.12[b]	23.3±3.90
Hb (g/dL)	11.4±1.17[ab]	12.5±1.63[a]	10.3±1.50[b]	11.3±1.73
Leukocytes (x10[6]/uL)	8.24±2.97[b]	11.34±4.55[a]	9.6±2.61a[b]	9.9±3.59
Lymphocytes (%)	36.9±19.06[b]	30.7±12.26[b]	47.9±12.05[a]	39.5±15.69
Neutrophils (%)	51.8±9.77[a]	51.7±14.73[a]	41.4±12.77[b]	47.3±15.73
N/L ratio	1.9±1.17[a]	2.1±1.3[a]	1.0±0.66[b]	1.6±1.12
Monocytes (%)	1.9±1.10	1.5±1.19	1.6±0.90	1.6±1.03
Eosinophils (%)	9.5±3.98[b]	16.2±6.55[a]	9.1±5.61[b]	11.61± 645
Basophils (%)	0±0.00	0±0.00	0±0.00	0±0.00

Different superscripts at the same row indicate significant differences (P<0.05).

The plasma cortisol levels in all research areas are not different even though the experienced heat stress of the dairy cows were different. The cortisol concentration would be increased under acute heat stress, but not under chronic heat stress or prolonged heat stress. The condition is in accordance to research by Silanikove (2000) that reported an inhibited cortisol production under prolonged heat stress to avoid overloaded body heat. The low plasma cortisol levels under prolonged heat stress showed the HF cow's ability to adapt to heat stress. The capability of the lowland raised HF cows to adapt to the heat stress is also supported by its haematological profile which is not different from the HF dairy cows which raised in the lower-upland area. The result is in accordance with Sejian *et al*. (2013) and Suprayogi *et al.* (2017) who stated that haematological profile represent the cow's health condition and its adaptation capability.

The haematological profile of the dairy cows also showed its physiological condition. The haematological profile of HF dairy cows in all research areas showed a significant difference (P<0.05) in the total erythrocytes, PVC, Hb levels, and leukocytes parameters. The highest erythrocytes concentration was shown on HF dairy cows which raised in the lower-upland area, followed by the HF dairy cows which raised in the upland area, while the lowest was in the lowland area. The erythrocytes concentration in this research was around 6.4 to 9.1x10^6/uL. The Hb levels and PVC of the lowland and lower-upland raised HF dairy cows was higher compared to the HF dairy cows which raised in the upland area. The HF dairy cows which raised in the upland area had the lowest PVC, in which in accordance to the lower erythrocytes concentration of the dairy cows compared to the dairy cows which raised in the lower-upland area. The highest Hb concentration was shown in the HF dairy cows which raised in the lower-upland area, followed by the HF dairy cows which raised in the lowland area and the lowest was found in the upland area. The Hb concentration of the HF dairy cows in all research areas was around 10.3 to 12.5x10^6 g/dL. The high erythrocytes, Hb, and PVC on the HF dairy cows which raised in the lowland and lower-upland area are allegedly caused by dehydration. The HF dairy cows which raised in the lowland and lower-upland area experiences moderate stress thus caused an increase in body heat production and resulted in a more active thermoregulation process. The result is similar to report by Sattar and Mirza (2009); Alameen and Abdelatif (2012) which stated that dairy cows which raised during dry season would experience heat stress and resulted in an increasing Hb concentration and PVC.

The average leukocytes concentration of the HF dairy cows in all research areas in this research is 9.9 ± 3.59. The result is in accordance to research by Gavan *et al*. (2010) and Mirzadeh *et al*. (2010). The lymphocytes level in each research areas is lower than normal, but on the contrary, the neutrophils were higher than normal. The monocytes, eosinophils, and basophils levels in all research areas are at a normal level according to Gavan *et al*. (2010) and Mirzadeh *et al*. (2010). The low lymphocytes level (lymphopenia) could occur with low milk production and heat stress. The varying results were regarding to the various factors which affect haematological profile, such as the dairy cow breeds, age, body weight, lactating period, milk production, sex, heat stress, disease, and its adaptation capability to the environment (Satta and Mirza, 2009; Bhan *et al*., 2012). In general, the haematological profile of HF dairy cows in all research areas is normal. This showed that all of the dairy cows showed a good adaptation capability even under heat stress condition.

Milk production

The average milk production in all research areas was significantly different (P<0.05). The average milk production, 4% FCM corrected milk production and the produced milk quality of HF dairy cows in all research areas are presented in Table 6. It can be seen that the average milk production of HF dairy cows which raised in upland area is 16% higher compared to the dairy cows which raised in the lower-upland area and 87% higher compared to the cows which raised in the lowland area. The different milk productions of the dairy cows were caused by several factors, such as different environments, consumed feeds,

Table 6. The milk yield of the HF dairy cows at different land elevations

Milk yield (kg/day)	Lowland	Lower-upland	Upland	Mean Value
Mean value	7 ± 3.36[c]	11.3 ± 4.73[b]	13.1 ± 3.52 [a]	9.9 ±4.65
4% FCM correction	6.5 ± 3.73[b]	11.4 ± 6.12[a]	11.7 ± 5.29[a]	9.2±5.47

Description: Different superscripts at the same row showed significant differences (P<0.05).

and its internal aspects. In general, the HF dairy cows which raised in the upland area was raised in a more comfortable environment, with larger body size and better feed intake. The statistical analysis showed that the average temperature, humidity, THI and feed intake in all research areas had a significant effect on milk production.

In terms of milk production, in which corrected with 4% FCM, the HF dairy cows that raised in lower-upland and upland area had similar milk production. The obtained result is caused by the better milk fat content on HF dairy cows which raised in the lower-upland area compared to the upland area. The milk quality produced by upland raised HF dairy cows is lower to the lowland and lower upland in terms of fat, protein, dry matter and undissolved dry matter content in the produced milk. The result is in accordance with the research by Hill and Wall (2015) and Rahayu *et al*. (2015) which reported that milk production is in reverse to the milk quality. The dairy cows which produced high milk yields had lower milk quality compared to the cows which had low milk productivity.

The result of this research showed that the ideal microclimates condition for HF dairy cows is in the upland area. Moreover, it also showed that for every increased land elevation would be resulted in a decrease in temperature and an increase in air humidity (Table 3) and decreased milk production (Table 6).

The result is affected by the dairy cow’s requirement to the suitable air temperature and humidity to reach optimal production. Berman (2005) reported that the best production of the dairy cows would be achieved when the cows were raised in the environment with 18ºC temperature along with 55% humidity. Air temperature and humidity which were outside of the comfort zone for the dairy cows would cause heat stress, an increase in physiological responses (Gantner *et al*., 2011) and declining productivity (Silanikove, 2000; Gantner *et al*., 2017).

The highest heat stress was occurred on the lowland raised HF dairy cows, and significantly affect its productivity. The milk production of lowland raised HF dairy cows was 87% lower compared to the upland raised HF dairy cows. Moreover, the lower-upland raised HF dairy cows had 16% lower milk productivity compared to the upland raised dairy cows. The lower milk production of lowland raised HF dairy cows compared to the other research areas even though there were not any differences on the raising and feeding management showed how the environmental condition affect the HF dairy cow’s productivity and the cow’s adaptation capability to the heat stress, noting that milk production would increase the heat stress sensitivity. Purwanto *et al.* (1990) reported that dairy cows which produced 18.5 kg of milk daily produced 27.3% higher heat production compared to the non-lactating cows while lactating dairy cows with 31.6% milk production produced 48.5% higher body heat. Berman (2005) reported that the heat stress threshold would be decreased as much as 5ºC for every 10 kg increased daily milk production. The dairy cows with good thermotolerance would tend to have lower milk production with higher total milk solids and persistence (Alameen and Abdelatif, 2012).

Conclusions

The Holstein Friesian (HF) dairy cows which raised in both lowland and lower-upland area were exposed to moderate heat stress, while the dairy cows which raised in the upland area experienced mild heat stress. In general, all of the HF dairy cows which raised in lowland, lower-upland, and upland showed the ability to adapt to the heat stress caused by the unfavorable environment. The HF dairy cows which raised in lowland adapt by increasing its body, rectal, and skin temperature, while also increasing its respiration rate to accelerate its body temperature reduction. On the aspect of productivity, the upland area is more ideal for the HF dairy cow farming, noting that the area has more suitable microclimate conditions to support the dairy cow productivity.

References

Al-Samawi, K. A., M. J. Al-Hassan, and A. A. Swelum. 2014. Thermoregulation of female Aardi goats exposed to environmental heat stress in Saudi Arabia. Indian J. Anim. Res. 48: 344-349.

Alameen, A. O. and A. M. Abdelatif. 2012. Metabolic and endocrine responses of crossbred dairy cows in relation to pregnancy and season under tropical conditions. American-Eurasian J. Agric. Environ. Sci. 12: 1065-1074.

Atrian, P. and H. A. Shahryar. 2012. Heat stress in dairy cows (a review). Res. in Zoology. 2: 31-37.

Badan Meteorologi Klimatologi dan Geofisika (BMKG) 2015. Outlook El Nino 5. BMKG, Jakarta.

Berman, A. 2005. Estimates of heat stress relief needs for Holstein dairy cows. J. Anim. Sci. 83: 1377-1384.

Bhan, C., S. V. Singh, O. K. Hooda, R. C. Upadhyay, Beenam, and V. Mangesh. 2012. influence of temperature variability on physiological, hematological and biochemical profile of growing and adult sahiwal cattle. J. Environ. Res. Develop. 7: 986-994.

Brosh, A., A. Cabiddu, M. Decandia, V.Giovanetti, and G. Molle. 2005. Energy expenditure of dairy goats supplemented with PEG browsing on Mediterranean bush land. In: Sustainable Grazing, Nutritional Utilization and Quality of Sheep and Goat Products. E. Molina Alcaide (ed). Ciheam, Zaragoza, pp. 255-260.

Campbell, T. W. 1995. Avian Hematology and Cytology. Iowa State University Press, Iowa.

Collier, R. J., J. L.Collier. R. P. Rhoads, and L. H. Baumgard. 2007. Invited review: genes involved in the bovine heat stress response. J. Dairy Sci. 91: 445-454.

Das, R., L. Sailo, N. Verma, P. Bharti, J. Saikia, Imtiwati, and R. Kumar. 2016. Impact of heat stress on health and performance of dairy animals: A review. Vet. World. 9: 260-268.

Direktorat Jendral Peternakan dan Kesehatan Hewan (Ditjennak). 2017. Statistik Peternakan dan Kesehatan Hewan. Kementrian Pertanian RI, Jakarta.

Gantner, V., P. Mijić, K. Kuterovac, D. Solić, and R. Gantner. 2011. Temperature-humidity index values and their significance on the daily production of dairy cattle. Mljekarstvo. 61: 56-63.

Gantner, V., T. Bobic, M. Gregic, R. Gantner, K. Kuterovac, and K. Potocnik. 2017. The differences in heat stress resistance due to dairy cattle breed. Mljekarstvo. 67: 112-122.

Gavan, V., M. Woloszyn, F. Kuznik, and J. J. Roux. 2010. Experimental study of a mechanically ventilated double-skin facade with venetian sun-shading device: A full-scale investigation in controlled environment. Solar Energy 84: 183-195.

Hahn, G. L. 1999. Dynamic responses of cattle to thermal heat load. J. Anim. Sci. 77: 10-20.

Hill, D. L. and E. Wall, 2015. Dairy cattle in a temperate climate: the effects of weather on milk yield and composition depend on management. Anim. 9: 138-49.

FAO. 2011. Guide to Good Dairy Farming Practices. Animal Production and Health Guidelines. FAO, Rome.

Kumar, S., K. Ajeet, and K. Meena. 2011. Review: Effect of heat stress in tropical livestock and different strategies for its amelioration. J. Stress. Physiol. Biochem. 7: 45-54.

Marai, I. F. M., A. A. El-Darawany, A. Fadiel, and M. A. M. Abdel-Hafez. 2007. Physiological traits as affected by eat stress in sheep—A review. Small Rumin. Res. 71: 1-12.

McLean, J. A., J. A. Downie, C. D. R. Jones, D. P. Stombough, and C. A. Glasbey. 1983. Thermal adjustment of stress (*Bos taurus*) to abrupt changes in environments temperature. J. Agric. Sci. 48: 81-84.

Megahed, G. A., M. M. Anwar, S. I. Wasfy, and M. E. Hammadeh. 2008. Influence of heat stress on the cortisol and oxidant-antioxident balance during oestrous phase in buffalo-cows (*Bubalus bubalis*): Thermo-protective role of antioxidant treatment. Reprod. Dom. Anim. 43: 672-677.

Mirzadeh, K. H., S. Tabatabaei, M. Bojarpour, and M. Mamoei. 2010. Comparative study of hematological parameter according strain, age, sex, physiological status and season in Iranian cattle. J. Anim. Vet. Adv. 9: 2123-2127.

NRC. 2001. Nutrient Requirement of Dairy Cattle. National Academi Press, Washington DC.

Nardone, A., B. Ronchi, N. Lacetera, M. S. Ranieri, and U. Bernabucci. 2010. Effects of climate changes on animal production and sustainability of livestock systems. Livestock Prod. Sci. 130: 57-69.

Purwanto, B. P., Y. Abo, R. Sakamoto, F. Furumoto, and S. Yamamoto. 1990. Diurnal patterns of heat production and heart rate under thermoneutral conditions in Holstein Friesian cows differing in milk production. J. Agri. Sci. 114: 139-142.

Purwanto, B. P., F. Nakamasu, and S. Yamamoto. 1993. Effect of environmental temperatures on heat production in dairy heifers differing in feed intake level. AJAS. 6: 275-279.

Rahayu, A. P., S. Johari, and E. Kurnianto. 2015. Genetic gains of milk yield and milk composition as realized response to dairy cow selection in BBPTU-HPT Baturraden, Indonesia. J. Indonesian Trop. Anim. Agric. 40: 79-86.

Reece, W. O., H. H. Erickson, J. P. Goff, and E. E. Uemura. 2015. Dukes' Physiology of Domestic Animals. Wiley-Blackwell, Oxford.

Schütz, K., A. Rogers, N. Cox, J. Webster, and C. Tucker. 2011. Dairy cattle prefer shade over sprinklers: effects on behavior and physiology. J. Dairy. Sci. 94: 273-283.

Sattar, A. and R. H. Mirza. 2009. Haematological parameters in exotic cows during gestation dan lactation under subtropical conditions. Pakistan Vet. J. 29: 129-132.

Sejian, V., V. P. Maurya, K. Kumar, and S. M. K. Naqvi. 2013. Effect of multiple stresses on growth and adaptive capability of Malpura ewes under semi-arid tropical environment. Trop. Anim. Health Prod. 45: 107-114.

Silanikove, N. 2000. Effects of heat stress on the welfare of extensively managed domestic ruminants-a review. Livest. Prod. Sci. 67: 1-18.

Sivakumar, A. V. N. and G. Singh. 2010. Varshney antioxidants supplementation on acid base balance during heat stress in goats. AJAS 23: 1462-1468.

St-Pierre, N. R., B. Cobanov, and G. Schnitkey. 2003. Economic losses from heat stress by US Livestock Industries. J. Dairy Sci. 86: E52-E57.

Soltan, M. A. 2010. Effect of dietary chromium supplementation on productive and reproductive performance of early lactating dairy cows under heat stress. J. Anim. Phys. Anim. Nut. 94: 264-272.

Suprayogi, A., G. Alaydrussani, and A. Y. Ruhyana. 2017. Nilai hematologi, denyut jantung, frekuensi respirasi, dan suhu tubuh ternak sapi perah laktasi di pangalengan. Jurnal Ilmu Pertanian Indonesia 22: 127-132.

Todini, L., A. Malfatti, A. Valbonesi, M. Trabalza-Marinucci, and A. Debenedetti. 2007. Plasma total T3 and T4 concentrations in goats at different physiological stages, as affected by the energy intake. Small Rumin. Res. 68: 285-290.

Yani, A. dan B. P. Purwanto. 2006. Pengaruh iklim mikro terhadap respons fisiologis sapi Peranakan Fries Holland dan modifikasi lingkungan untuk meningkatkan produktivitasnya (Ulasan). Media Peternakan 29: 35-46.